

Report on the Atlantic herring hydroacoustic research at the Northeast Fisheries Science Centre Woods Hole MA.

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1 Background

The hydroacoustics survey and analysis process is technologically complex and is not familiar to all stock assessment scientists. However, this technique is well developed and has been used to provide tuning data for a number of pelagic stocks (Anon 2001) and now provides the most precise assessment tuning index used for the management of North Sea herring ICES (2002). For the North Sea herring stock a survey index has been available for the last 12 years. This survey that started as a series of exploratory cruises in 1979-1983, was providing data on the complete adult stock by 1984 and has been organised in a coherent form since 1989. This compares with the IBTS bottom trawl survey, which started in 1971, was co-ordinated by 1983/84 and is used in the same assessment from that date. Many of the design, analysis and error issues in hydroacoustics are common to net-based survey methods. In particular for the trawl survey the estimation of swept area of a fishing gear for different species under different tide, light level, towing speed, warp length and bottom types is analogous to the estimation of target strength in an acoustic survey for a species under different depth and light level conditions. Hydroacoustics is a relatively well-developed field in fisheries providing an excellent framework for the estimation of fish distribution and abundance (MacLennan and Simmonds 1992). Hydroacoustics is used in fisheries on over 40 countries and in all the worlds' oceans to provide estimates of pelagic populations. In the North Atlantic the ICES FAST (Fisheries Acoustics Science and Technology) working group provided a forum for development of fisheries hydroacoustics.

This report is intended to provide both a review of quality control and data collection procedures at NEFSC to date and advice on the future direction of the survey design and supporting research.

2 Description of the review

This report details a review of the Atlantic herring hydroacoustic research at the Northeast Fisheries Science Centre (NEFSC). It includes a review of the survey design, operational procedures, data analyses, and biomass estimates for Atlantic herring and has been carried out following receipt of a description of the work (Michaels et al 2001) received on 20 November 2001 and a report on the Northwest Atlantic Herring Acoustic Workshop Darling Marine Centre, Walpole, Maine during March 13 - 14, 2001.

Following discussions on the work of the survey programme at a meeting held at Woods Hole 3-6 December 2001. Participants at the meeting were: -

Vaughn Anthony
William Michaels
Wendy Gabriel
Michael Jech

William Overholtz
Elizabeth Pratt
John Simmonds
Chris Stevens

The report was prepared during the period 15 December 7 January in Aberdeen Scotland.

3 Summary

The report highlights the main issues for the further development of the survey to obtain initially a good age disaggregated index of abundance of herring and in the longer term the development to provide an absolute estimate of abundance at age. The report concentrates on the details of equipment and procedures. For efficiency it necessarily concentrates on the main issues for change and development. It should be clearly understood that in general the survey is developing well and that the vast majority of equipment, and working methods are of a high standard. It is anticipated that in the short term this survey will deliver an index of abundance for Georges Bank herring. In the longer term it should be developed to give absolute abundance. Throughout the discussions of the programme it was apparent that the data collection and the analysis was sensitive to the provision of long-term staff for trained specifically to help with acoustic survey data collection and analysis. There was a clear need for increased high quality technical support to be employed in a way and at a level that would be likely to provide staff retention to assist with the data collection at sea and to carry out data analysis on shore.

In particular the staff involved are of a high standard and are providing a good service. The sounder systems are up to date and capable of delivering quality data. The database systems are either already of a high standard or in the process of being developed appropriately. The analysis methods employed are generally appropriate. The primary area and time selected for the survey seems to be correct. In the longer term the aim is to move the surveys from estimates of an index of abundance to provide estimates of absolute abundance. This requires development of good target strength relationships from a combination of modelling and measurement. This work should be encouraged and supported. Some work on survey design and geostatistical analysis of survey data has been carried out this should be developed. The area covered by the survey and the strategy should be reviewed periodically in the light of the estimates of year class strength found on each annual survey. The current links with other groups involved in acoustic surveys in the Northeast of North America should be strengthened. The current workshop system should be developed. The possibility of setting up a small management group to support and set TOR for regular meeting of this group should be considered.

Primary areas for attention.

There is a need to ensure that cannibalisation of the scientific sounder systems does not take place by providing sufficient spares for EK500 systems.

The use of the current value for sound velocity needs to be checked.

The quality control procedures for ensuring correct selection of calibration spheres for each of the different frequency sounders needs to be improved.

Currently fishing gear maintenance does not provide adequate quality assurance. Maintenance of the pelagic fishing gear should be more formally organised to ensure the gear is kept in good order and repaired to a standard.

A period of time should be built into the vessel replacement programme to provide for inter-calibration between the new vessel and RV Delaware. This should include both acoustic data collection and fishing.

Following the range of track designs tried over the period 1998 to 2000 it is time to choose one type of track design for the survey of Georges Bank. (An appendix is included to help with the choice of design.)

While concentrating on the Georges Bank survey, consideration should be given providing coverage over other parts of the Gulf of Maine to ensure that important parts of herring stocks are not missed. Co-operation from other institutions should be sought to support this.

The information on proportions of herring at age needs to be checked in the 2001 surveys (not included in this review). Otolith exchanges should be arranged with other institutions around the Gulf of Maine with the possibility of an otolith reading workshop. Consideration should be given to increased biological sampling (both numbers of trawls and numbers of otoliths at length) to give increased confidence in the proportions at age.

The current use of Target Strength data from the North Sea surveys should be replaced by the work of Foote (1987). The method of calculation should be modified slightly (see below). In the longer term attempts should be made to incorporate locally derived TS relationships within the survey.

4 Review of current methods and procedures

4.1 Main Acoustic and Data Systems

A full description of the equipment currently used at NEFSC is provided in the description of the work provided to the reviewers (Michaels et al 2001). In general with minor exceptions the equipment is sufficient for the current needs of the survey and data analysis and fit for purpose. No attempt has been made to re-document equipment use only the main issues regarding the current installations and their use are presented:

4.1.1 Scientific vertical echosounder

The Simrad EK500 Sounder is available on both main research vessels. While recently superseded with a new model (EK60) it remains the scientific standard instrument for fisheries acoustic surveys. The new instruments now provide more

flexible installation increased vertical definition with increased sample rates but little other benefits. The EK500 remains the industry standard for hydroacoustic surveys. While the newer model should be fitted to any new vessels care will be needed in the early stages until the instrument firmware becomes stable. Currently the EK500 system is used with three frequencies. The practice of data collection at three frequencies should continue and where possible this information should be formally incorporated into the analysis procedure. Current system control and monitoring of system settings are adequate for the purpose.

Spares

The exact extent of spare parts was unsure but examples of the existing instruments being cannibalised to maintain the operation of some vessels were encountered. Running such scientific measurement systems with inadequate supplies of spares is not acceptable. Two improvements are required:

- a) Access to spares: NOAA vessel operations should ensure that they (or a local Simrad agent) should hold sufficient spares available at a reasonably (24 hour) notice to replace any single failure. Cannibalisation should always be a last resort and should never be a routine method for repair and maintenance.
- b) Tracking of board serial numbers: A record of board serial numbers in any EK500 should be kept and updated if any changes are made. This will improve the confidence in equipment reliability and calibration.

Sound Velocity

Currently at NEFSC the EK500 is used with a fixed sound velocity profile either a single value or with a linear profile from surface to a defined depth. However, there is good data available to indicate that the hydrography around Georges Bank is quite variable. The influences of these changes are relatively easy to check. The current value of 1460 m/s (suitable for approximately 31ppt salinity and 4°C) seems rather low for oceanic conditions on Georges Bank and needs to be checked. The mean value should be checked as a high priority, the inclusion of variable profiles is a lower priority.

Calibration

Some discrepancies in the calibration were found (Table 2.1.2 in Michaels et al 2001). These reported changes in performance were too large for normal variability encountered with this instrument. These discrepancies were discussed at length and it was decided that the most likely explanation for the fluctuations was that the incorrect calibration sphere was deployed on a series of calibrations. The performance differences were fully resolved by this explanation. Quality control procedures need to be improved to ensure that this type of problem cannot happen again. The survey results from this period where the incorrect sphere was used need to be re-scaled by the difference target strength between the sphere used and the value assumed for the calibration sphere. There are some differences in the methods required for calibration from those provided in the Simrad manual these are presented in a survey manual prepared as part of the ICES planning group for herring surveys (PGHERS) this is included in the 2000 report (Anon 2000 appendix 6). In particular care should be taken to ensure the range of the sphere is measured correctly.

Currently the surveys are carried out on RV Delaware with a hull-mounted transducer system. Wiring is thought to be robust. However, if systems are deployed on vessels

of opportunity, for example to cover some of the inshore ledges there may be a need to use towed systems. Should this be the case towing cables should be regarded as consumable items and the impedance of the cable checked regularly (daily) under load (while towing) to ensure cable integrity. Drop out on a single quadrant on a split beam transducer may not always be apparent to an operator. Checks on cable continuity provide the required checks.

4.1.2 Acoustic data processing / software

For post processing of acoustic data recently the NEFSC moved from the use of Simrad BI500 system to Sonar Data Echoview software. This new system currently provides the best commercially available processing software. It is ideally suited to provide the quality control required to apply and record all the parameters used in processing the basic echosounder data. It is a well-supported product with relatively good quality control on updates. It is recommended that in the medium term this product should provide the first stage of acoustic data analysis. Finance for licences including the 'virtual echogram' module and annual updates need to be guaranteed.

QA of Echoview Output:

The output from Echoview needs to be checked and validated before it is extracted to the main fisheries database. Currently the methods used for this allow for tools such as post plots and histograms to give visual checks on data. Data is exported into temporary databases and can be checked, using suitable tools. As the database system becomes more mature, more formal arrangements will be required to ensure that data records can be overwritten if errors are found during the quality control process. The database system should be designed to allow the creation of temporary data records followed by a signing off procedure for validated data. Failure to provide these facilities will result in the need to maintain parallel output and visualisation tools that would be inefficient to maintain.

Noise Spikes:

Although the sounder system is synchronised with the EK500 echosounder on RV Delaware, there was evidence of noise spikes and interference with other sounders or sonars, including some anecdotal evidence for interference from fishing vessel sonars. Under these circumstances, as immunity from noise cannot be guaranteed, there is a need for a good method for removal of noise spikes. The virtual echogram system within Echoview using appropriate convolution filters should help with this process. In particular a median filter is known to be particularly suitable for removal of noise spikes. Echoview provides the correct convolution method but does not currently implement a median filter; efforts should be made to co-ordinate requests within the acoustics community for the inclusion of such a filter.

Threshold Levels:

The current processing used at NEFSC uses –66dB threshold level. The basis for this choice has been examined and seems well founded. This choice of threshold level has been shown to contribute only a small percentage error to any estimate. Data processing using the virtual echogram module in Echoview provides methods that are even less sensitive to threshold. Improvements in this area could be explored but should be given a low priority.

Use of Target Strength information

Currently NEFSC use the same equation as the ICES co-ordinated acoustic survey in the North Sea. This relationship was developed from data available in 1984. The survey is used as an index of abundance for herring assessment so the value is not important. As NEFSC wishes to develop this survey into a measure of absolute abundance there is a need to select and use the best available herring Target Strength information. Currently the most comprehensively reviewed TS data is published by Foote (1987) Following the work in the early 80's there has been a reduced effort internationally on collection of herring TS data and little new work has been published. Currently the FAST WG has a study group reviewing TS data for Baltic herring. Their report documents current sources of data on herring TS. In the short term it is recommended that NEFSC use the Foote relationship for herring. In the medium term the results of the FAST WG investigations of herring TS should be examined and in the light of this the use of this equation re-evaluated. In the longer term NEFSC should develop its research effort to obtain local TS data. (See section on research needs below).

Currently most of the survey work is carried out using directly identified traces of herring. Thus only the TS relationship for herring is required. There may be occasions where there is a need to separate herring as a mixture. In this case relationships will be required for other species. Relationships for other species can be found in Foote (1987) and in MacLennan and Simmonds (1992). However, if possible, regional agreement on the values used should be reached. Further meetings of the Northwest Atlantic Herring Acoustic Workshop should be encouraged and this group should be asked to recommend appropriate relationships for the region.

Target Strength is known to vary locally due to fish size, gonad development, fat content, fish depth location and depth history. Currently in the survey area TS values are only varied according to fish size. This restriction is common practice (Anon 2000). However, establishing a fully parameterised Target strength model for herring will be difficult and should be carried out with care. When deciding when to implement such a model the group should balance the improvements obtained by implementation of a spatially temporally varying TS function against the lower variability obtained when using a fixed value. The decision to change methodology should be taken only once the model has been shown to provide improvements. In the medium term the model should be developed, and when the parameters are well enough known and the variables can be measured sufficiently precisely to provide improvements in mean square error of the estimate it should be used within the survey estimate. It would then be advisable to maintain an analysis both with and without varying TS until the method using variable TS has been shown to perform better.

4.1.3 Omnidirectional Sonar.

This sonar is suitable for general observation of fish schools in the vicinity of the vessel. The sonar has been synchronised with the other sounders thus reducing interference and making it possible to operate this instrument along with the EK500 sounder. While this sonar provides an acceptable quality for general observation, use for quantitative work is likely to be difficult, because of the absence of a digital data output and because the instrument uses AGC (automatic gain control). Screen capture

methods could be improved with the use of screen capture computer systems. However, the internal operation using AGC (automatic gain control) will always make the quantitative use of this device unreliable. Currently the methodology, choice of time and location, selected for these acoustics surveys does not appear to suffer from vessel avoidance (see below under noise) but this has not been explicitly checked. Should there be a need to investigate vessel avoidance in the longer term a more suitable sonar or multibeam sounder such as the SM2000 used by the Canadian group (Anon 2001) will be required.

4.1.4 Pelagic Trawl

The Pelagic rope trawl currently used on the survey seems well suited to the purpose, observations with the trawl mounted sonar indicates that the herring found on or close to Georges Bank can be caught very easily with this gear. If a more detailed review of its performance is required the views of a gear technologist with pelagic fishing gear expertise should be consulted. Some difficulties were reported with use of the pelagic gear, due to a lack of familiarity with pelagic deployment on the NOAA vessels. This could be improved by firstly producing a handling manual providing all the trawl deployment requirements including warp lengths and vessel speed combinations for shooting and recovery. Secondly by videoing the deployment at the end of the trip when everything is working well and providing the video to the crew and fishing mates for viewing at the start of the subsequent trips.

Currently the fishing gear repair arrangements appear to be poor, relying more upon good will than a properly funded agreement. The pelagic gear is used to obtain species proportions and size ranges of herring; thus it is effectively a measurement instrument and needs to be properly maintained. There should be a clearly identified and funded arrangement to maintain the pelagic trawls. This could be implemented either by extending the locally organised demersal trawl arrangements to include pelagic gear, or formal arrangements within NOAA using the gear group in Seattle. If shipping costs and/or repair times are excessive a local commercial arrangement could be established if this is available.

The current rigging of the gear is not suitable for sampling very close to the surface or in shallow water. The current gear should be examined to see if it could be deployed near the surface using buoyed deployment. For shallow water a suitable smaller pelagic gear should be found.

4.1.5 Trawl monitoring system

The FS903 used to monitor trawl performance provides an excellent instrument for this purpose.

4.1.6 Under water video system

This system has developed in a rather *ad hoc* fashion but is currently capable of providing good ancillary supporting data on species composition and more importantly fish orientation (see below section on TS research). It is unlikely that it will be possible to make simultaneous observation on fish target strength and

orientation *in situ* using an EK500 for the acoustic data collection, however, the system should be capable of providing essential data on the distributions of fish orientation.

Data processing of stereo images.

There is a need to develop digital processing to extract fish orientation automatically from stereo images. Standard frame grabbing and image-processing software is available to extract objects in images, however, some development is required to automatically extract orientation efficiently. This type of software development forms a well-defined task with a good mixture of development and innovation within a standard environment. While the techniques are relatively standard any implementation of such a system will need to be tuned to the local picture quality, water visibility and object (fish) size as well as the orientation data required. The possibilities of using a studentship for this type of development could be investigated.

The current TV system is organised for cast deployment it is being moved to a towed system. As unit orientation is crucial for evaluation of the data the recording rate and of the motion sensor and its immunity from acceleration needs to be checked before the system is used in towed mode.

4.1.7 On board data management system

SCS Event Log

The even log based system developed for operation on NOAA vessels provides a good system for data quality assurance. The system should be capable of providing the documentation to define which acoustic records are parts of the survey and which should be excluded. It is important that the data from this system is incorporated into the database system being developed for Echoview output. The current intention is to use the echosounder log as the key field in a record. It is thought that this is more reliable than time because the echosounder runs its own clock which must be synchronised on regular basis but may lead to uncertainty in record allocation as the echosounder time will not always be synchronised with the ships computer system time.

Fisheries Scientific Computer System (FSCS)

This system provides a good method for quality control of biological data. The current system operates to 1 cm. precision; the system is capable of operating to 1/2 cm. precision and if possible data should be stored with this precision. As a general rule there is little point in removing precision that is available.

4.1.8 Vessel Performance / Replacement

The RV Delaware while old does seem to be generally suitable for acoustic surveys. Only one main issue cannot currently be addressed. ICES has recommended that as the noise performance of research vessels will influence their performance the noise emission requirements should be calculated based on the species, distance to fish aggregations to be observed (ICES). Vessels should then be built to conform to these needs. While the noise emitted by the main survey vessel RV Delaware is currently unknown there are anecdotal reports that the vessel is noisy. There are plans to

replace this vessel with a new vessel as part of the NOAA fleet modernisation. For historic consistency noise measurements of this vessel would be interesting and should ideally be carried out before the vessel is taken out of service. The results of these measurements could be compared with the noise emissions from the new replacement vessel, which should be measured at the time of delivery to check conformance to the specification.

However, rather than the noise itself it is the influence of noise on the surveys that is more important. As currently there are no deterministic relationships between noise and survey results measuring the noise *per se* will not provide the information required to establish the influence of the noise on surveys for herring. It is therefore important that time be allocated in the replacement programme for a vessel inter-calibration between the new vessel and RV Delaware. The inter-calibration should include elements for both fishing and acoustic data collection. The fishing comparisons should concentrate on the estimation of species proportions and size which influence the acoustic surveys rather than catch rates.

4.2 Survey design and data analysis

The design and analysis issues are dealt with.

4.2.1 Survey design

The surveys have been carried out using a number of different predetermined design strategies. It would be preferable now to decide on one design approach and stay with this for some time. The most important aspect of the design decision is the choice of time of year for the survey and area to be surveyed. The results presented suggest that the area chosen for the survey of Georges Bank is now relatively well established and the period for the survey also well defined. It is important that as this survey is directed at a pre-spawning aggregation and the population is concentrating in the target area the survey extends to the limits of the aggregation. In general it will be necessary to carry out at least one transect at each end that is zero or very low density and to ensure that the northern ends of the transects extend to zero or low-density areas.

There remains a question of whether the Georges Bank spawning stock is a self-contained or part of a larger population covering other areas within the Gulf of Maine. At this stage the evidence is not conclusive and it would be helpful to cover some of the other potential herring areas either within the NEFSC survey program or with the help and co-operation of other organisations with interest in Gulf of Maine herring. It may be possible to organise this through the acoustic survey workshops. (See section on institutional links)

In addition to the track plan there is a need to collect biological data. This need is discussed in more detail under the section dealing with estimates of numbers at age and the section dealing with surveys under research needs. It is important to collect sufficient biological samples to support the identification of acoustic traces and to provide the age structure with sufficient precision to track cohorts.

The issue of the type of survey track design to select is a rather general one and is not included within the body of the report but is dealt with in a separate appendix (Appendix 1 Survey Design). This appendix addresses the issues of systematic or random design, parallel or zigzag transects.

There is only one other specific issue that should be considered for the Georges Bank survey. There are indications that the vertical distributions of herring may be dependent on time of day, particularly changes with day and night, and also with water depth, as the density changes on and off Georges Bank. If this is the case then it would be helpful to ensure that as far as possible the survey is organised with an even coverage at day and night and over depth. Currently the transects are of a length (duration) that could end up with samples in the shallower water at the southern end all at night and the northern end in deeper water during the day or *visa versa*. Care should be taken to ensure that as far as possible this does not happen. As a general rule if there is a perception that distribution or abundance are dependant on several variables and that the survey may be sensitive to this the survey should be designed with this in mind. In general the designs should ensure that where possible data is collected without inadvertently correlating the measurements of these variables.

4.2.2 Data analysis

The equations and relationships required for survey data analysis are collated in Simmonds *et al* (1992).

Estimating abundance and biomass

The data analysis methods for estimating biomass, abundance and numbers at age are being carried out correctly with the minor exception of the calculation of mean target strength. The correct method is given below and should be implemented in the NEFSC software. It is anticipated that the change will be very small. The issue of different calculation methods is highlighted in the report on the Northwest Atlantic Herring Acoustic Workshop held in Walpole, Maine during March 2001. The method that should be used is presented by Claude Leblanc in this workshop report or in MacLennan and Simmonds (1992, equation 8.7 on page 245).

$$\langle \sigma_i \rangle = 4\pi \sum_j f_{ij} 10^{((a_i + b_i \log L_j)/10)}$$

And

$$TS_i = 10 \log(\langle \sigma_i \rangle / 4\pi)$$

Where TS_i is the mean target strength of the i^{th} species

f_{ij} is the frequency at length j for species i

L_j is the centre point of length of frequency class j

a_i and b_i are the coefficients on a TS length equation for species i .

Currently the survey is designed and implemented using fixed pre-planned strata. However, all strata are allocated equal effort (taking into account the area of the each stratum). The length frequency data from the trawl hauls and the age samples are used

for the whole survey area. The observations contain data on the spatial variability of herring size however, there will also be local measurement error. There are currently no well-developed methods for obtaining fully spatially varying length frequency distributions from a set of punctual observations. The data collected should be checked for spatial variability in length frequency. With more observations on herring size (and age) it may be preferable to divide the area into biologically based strata for estimating local length based herring Target Strength estimates, to be used in the analysis of abundance. One method for determining such biological strata is documented in MacLennan and Simmonds (1992 page 244 and appendix E). Simard (1995) has used a geostatistical kriging method for mapping length frequency distributions, kriging all the individual length frequency classes independently and then normalising each node to obtain a spatially varying pdf for length. This method may prove more flexible, but needs further investigation before it can be recommended.

Estimating proportions at age

The total numbers of herring at age estimated from the average of the surveys in 1999 and 2000 are given in Figure 2.2.1. This shows that the population estimated in the area is rather similar for both years. The change in numbers was only 13% of the mean suggesting consistency between surveys. When the numbers by year class are compared (Figure 2.2.2) the differences are rather bigger (here year class assumes the ages are expressed as age 0 in year of spawning, subtract 1 if an age are expressed as wr and remains zero for 15 months). The numbers in the 96-year class rise from 3.1 as age three to 5.5 billion at age four suggesting the possibility of a migration into the area perhaps as the herring mature. However, the estimates of numbers in 95 and 94 year classes in the two surveys are in conflict and more difficult to interpret. The numbers in the 95-year class rise slightly the numbers in the 94-year class more than halve dropping from 5.1 to 1.9 billion. This suggests either a directed fishery on older herring, which is unlikely, migration out of the area, which would be a problem for the survey, or inaccuracy in the estimates of proportions at age. The final possibility needs to be investigated as a priority. The split by age for each year's survey is based on 400 otoliths. This is rather small number of samples; however, it is unlikely that this lack of samples alone could result in such variability. Currently the 2001 surveys have not yet been fully analysed. It is important to complete this analysis and to compare the 2001 estimates of year class abundance for the 94 to 96 year classes with the earlier surveys.

Additionally, it would be useful to set up routine annual otolith exchange and regular multi-annual otolith reading workshops to provide long-term quality assurance for age structure determination. In addition there is a need to increase the numbers of biological samples to provide improved confidence in the estimates of proportions at age. The workshops could be organised through the standard methodology of Eltink et al. (2000) and the results analysed using the standard Excel spread sheet AGE_COMPARISONS.XLS. This sheet provides an exceptionally useful framework for analysis.

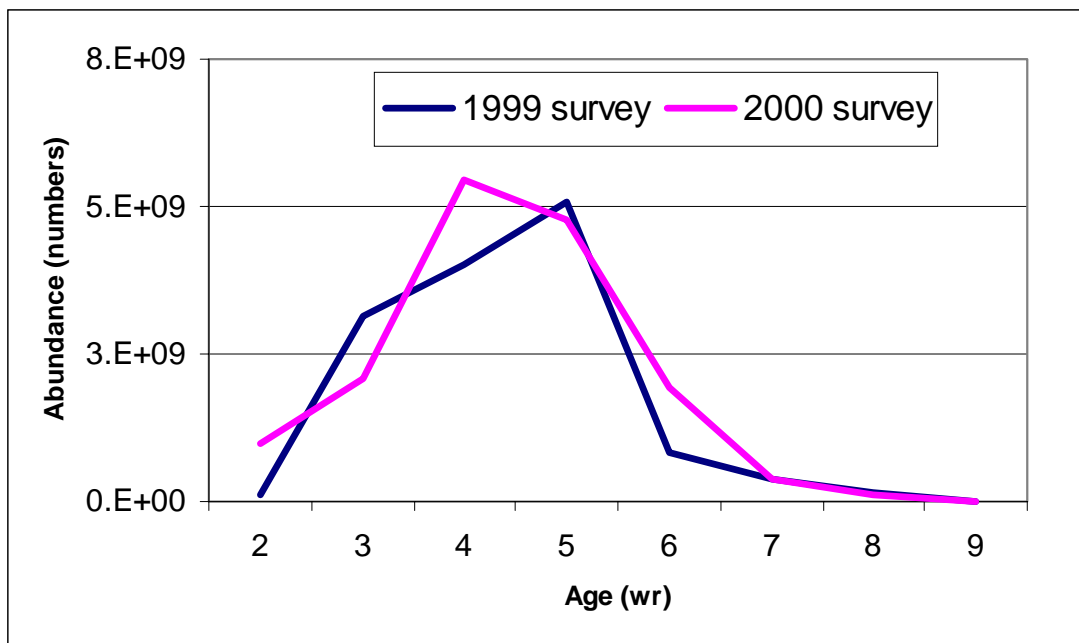


Figure 2.2.1 numbers of herring at age on George's Bank estimated from acoustic surveys in 1999 and 2000.

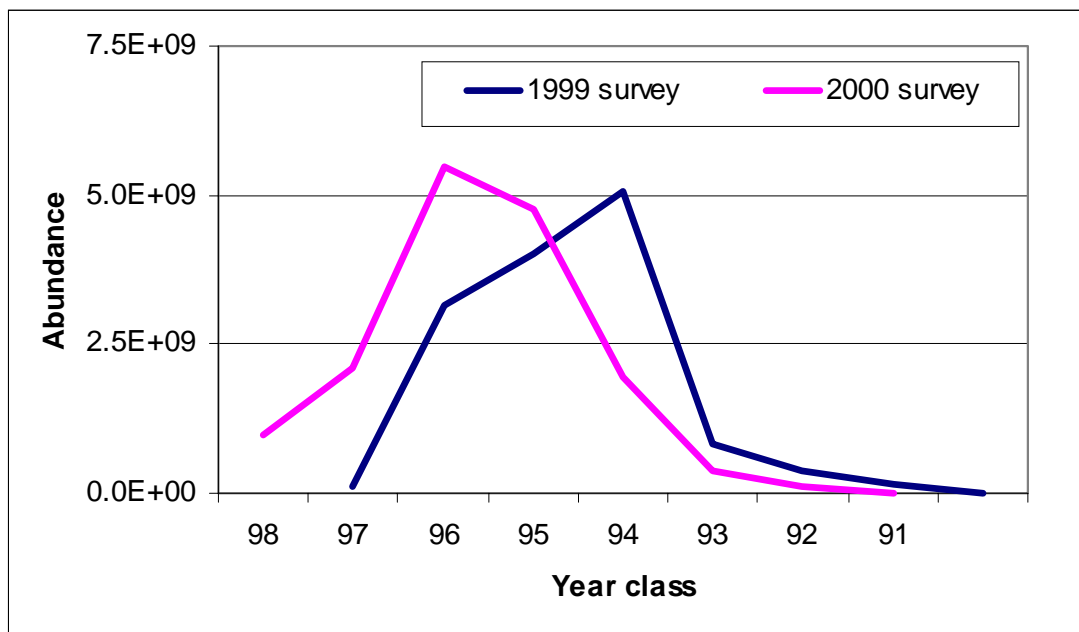


Figure 2.2.2 numbers of herring at age by year class on George's Bank estimated from acoustic surveys in 1999 and 2000.

Estimates of Variance

The methods currently used for estimating survey variances are appropriate for a random transect design, more complex methods should be applied with systematic designs (see section on survey design). The bootstrap method (Efron and Tibshirani

1993) provides a good estimate of the amplitude distribution and thus a method of obtaining 95% intervals. For acoustic data, which is effectively an exhaustive sample along a transect, the best choice of units to bootstrap is the transect values, thus it is the between transect information that is regarded as uncertain rather than the along transect data which is known exhaustively. However because the samples are assumed to be taken at random in a bootstrap, the spatial autocorrelation is not taken into account. The CV and the 95% intervals obtained from a bootstrap can be re-scaled to account for this. In general to calculate the 95% intervals on a survey estimate of biomass it is acceptable to invoke the central limit theorem and use limits appropriate to a normal distribution. The bootstrap analysis presented in the report seems to support the idea that the central limit theorem can be invoked. Geostatistical methods can be used to provide the appropriate variance (see Petitgas 1993 and Rivoirard et al 2000). Pierre Petitgas has produced an excellent analysis tool EVA2 (Petitgas and Lafont 1997). This tool is available free from the author who is currently working for IFREMER in France. This tool allows computation of both geostatistical variance estimators and classical sample variances so may be used to obtain the required ratio to modify the confidence intervals if the bootstrap method is used to obtain the frequency distribution. The co-operative work with Pat Sullivan should be encouraged.

4.2.3 Use of the survey estimates in assessment

The proposed methods for the use of acoustic surveys within the assessment are too preliminary to judge fairly. It is too early to use the surveys to provide absolute estimates of abundance within an age-based assessment. The current estimates of biomass (1999 onwards) may provide a good interim measure of the relative state of the population on Georges Bank. However, the reason for the variability in the estimates of numbers at age need to be established before the survey can be used in an age disaggregated assessment model.

4.3 Medium term research needs

The critical aspect for the use of an acoustic survey as an absolute estimate of abundance is the appropriate target strength that should be applied in the analysis. This is discussed briefly above for short term. However, there is a longer-term need to estimate a local target strength function for use with these surveys. The proposed method of the use of *in situ* experiments combined with laboratory experiments is the correct way to advance this work. It is important that both aspects should continue together and that the work be co-ordinated. Preliminary results indicate that there will be a number of difficulties to overcome before the results will provide the required accuracy for the surveys.

4.3.1 *In-situ* acoustical experiments in support of hydroacoustics survey abundance estimates

The proposed methods are appropriate. However, it seems unlikely that it will be possible to make individual measurements of fish target strength and fish orientation simultaneously from single fish. In the short term it is probably better to concentrate on obtaining distributions of target strength and fish orientation independently in the same situations. The methods for extracting single targets proposed by Demer et al

(1999) are a good way forward. The results reported show that only about 2% of potential single targets are then chosen as valid targets, and as the number of targets is limited to 30 per ping this may be less than 2% of the total energy from the aggregation. The mean of the resulting distribution of single targets has a long positive tail, and it is this tail (about 2% the selected values!) that dominates the estimate mean of the distribution. This is clearly a problem and the data cannot be used directly without supporting information. The modelling is required to provide that support. However, it may also be that improvements are possible by choosing to collect data in lower density areas as well as in high-density areas and if possible obtaining TS data at close range by lowering an acoustic system nearer to the fish traces. In addition, observations obtained during day and night should be compared. Bill Michaels is well suited to the requirements of this work and has put together an excellent video system to compliment the TS data collection systems. He has a good appreciation of the problems involved. Close co-operation with modelling work is essential.

4.3.2 Laboratory acoustical experiments in support of hydroacoustics survey abundance estimates

The modelling methods being employed at NEFSC are at the forefront of international research into suitable models for fish target strength. The links with John Horn at Washington State University and with the modelling group at Woods Hole Oceanographic Institution under Tim Stanton and Ken Foote should be encouraged. NEFSC is uniquely well situated to carry out this type of work and Mike Jech should be given every encouragement to develop this area of research. The modelling work should be regarded as complimentary to the *in situ* measurements. It should be used both to develop estimates of means but also to obtain information on the sensitivity of the estimates to fish behaviour including depth orientation and maturity state. The model-based probability distributions of TS (mean and distributional properties) should be compared to those obtained *in situ* to validate the modelling approach. Egil Ona and others have carried out parallel work on herring TS at the Institute of Marine Research in Norway using live fish in large pens, contacts with this group may prove fruitful. Links through the FAST WG study of Baltic herring target strength may also provide valuable information and contacts.

4.3.3 Survey design development

The issues for survey design have been discussed in some detail above and in the attached appendix. The current emphasis on testing a variety of track designs in practice is unlikely to bring much further benefit. The current issues for the survey design are the proportions of time to be spent collecting biological and acoustic data and the number of samples required to estimate proportions at age. Simmonds (1995) and Godo (1995) have addressed the first of these issues. In addition to this the most critical issues is the spatial and temporal location of the survey. Effort should be allocated to these areas of work.

4.4 Inter-agency co-ordination

There is *ad hoc* local inter agency co-operation with The Canadian Department of Fisheries and Oceans, The Gulf of Maine Aquarium, The Maine Department of

Marine Resources and the Island Institute. There are workshops held regularly to exchange ideas for acoustic surveys in the region. There are a number of ways in which working practices could be harmonised equipment could be shared and wider surveys could be co-ordinated. It would be a good idea to develop these workshops into a more formal management system. If the organisations concerned were to appoint a steering group to set annual terms of reference the workshop could provide an excellent opportunity for both informal exchange of ideas and for more formal co-ordination of a broader scientific program of acoustic surveys of the Gulf of Maine and Georges Bank.

Nationally NEFSC has links with the other NOAA fisheries science centres. The number of staff working in Fisheries Acoustics in these areas is small and regular contacts and co-ordinated research programmes should be encouraged. There are good personal links with Acoustics staff working in Seattle, delivering very high quality work on fish target strength these links should be fostered.

Internationally the ICES FAST WG under the ICES Fisheries Technology Committee provides an excellent forum for support in developing methodology for acoustic survey methods. Currently NEFSC staff participate in this WG, this participation should be encouraged and maintained. In 2002 ICES will be holding one of its period fisheries acoustics symposia. These occur at 5 to 8 year intervals and provide a unique international view of the state of fisheries acoustics science. Staff should be encouraged to participate in this as a matter of priority.

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6 Bibliography of materials provided

Anon 2001 Report on the Northwest Atlantic Herring Acoustic Workshop Darling Marine Center, Walpole, Maine during March 13 - 14, 2001 *NOAA Techn. Mem. 2002-xx* Edited by W Michaels

William Michaels Wendy Gabriel Michael Jech William Overholtz Elizabeth Pratt 2001 Summary of Atlantic Herring Hydroacoustic Research at the Northeast Fisheries Science Center November 19, 2001

7 Statement of work

A. General

The Northeast Fisheries Science Center (NEFSC) first implemented a fisheries acoustics research program in 1998 to estimate the abundance and biomass of Atlantic herring in the Gulf of Maine and Georges Bank regions. Although part of the review system in the on-going NEFSC Stock Assessment Review Committee process, the hydroacoustics survey and analysis process is technologically complex and is not familiar to most stock assessment scientists. A dedicated review of the survey design, operational procedures, data analyses, and biomass estimates for Atlantic herring is therefore appropriate, given the newness of the process, the highly specialized procedures involved, and the likelihood of provisions to open access to the fishery for this species to foreign joint ventures in the near future. Such a review would prove very useful for the US-Canadian transboundary assessment meeting, where results, if acceptable, could be incorporated in the assessment of the Atlantic herring stock complex.

The consultant shall conduct a review of the survey design, operational procedures, data processing and analyses, and biomass estimates before the assessments of Atlantic herring using fisheries acoustics can be used for fisheries management advice. The consultant shall conduct an onsite site review with NEFSC scientists to cover potential agenda items for the US-Canadian transboundary assessment meeting. Finally, the consultant shall complete a report that provides guidance for improving each item in the agenda, including:

- 1.) Survey design
- 2.) Operational methodology
 - a.) EK-500
 - b.) Omni-directional sonar
 - c.) Pelagic trawling
 - d.) Underwater video
 - e.) Other sampling
 - f.) Data management and processing at sea
 - g.) Calibration
- 3.) In-situ acoustical experiments in support of hydroacoustics survey abundance estimates
- 4.) Laboratory acoustical experiments in support of hydroacoustics survey abundance estimates
- 5.) Data processing and management
 - a.) Acoustical noise filtering
 - b.) Species partitioning of acoustical data
 - c.) Biological and physical data
 - d.) Data management (archival and accessibility)

6.) Data analyses

- a.) Density distributions
- b.) Backscatter and individual target strength estimates
- c.) Backscatter/length/weight/age relationships
- d.) Abundance and biomass estimates
- e.) Spatial, temporal and diurnal variability
- f.) Population assessment

7.) Inter-agency coordination

- a.) Canadian Department of Fisheries and Oceans
- b.) Gulf of Maine Aquarium
- c.) Maine Department of Marine Resources
- d.) Island Institute

B. Specific

The consultant's duties shall not exceed a maximum total of 2 weeks- several days to read all background documents, attend a three-day meeting with scientists at the NEFSC in Woods Hole, Massachusetts, and several days to produce a written report of the findings. It is expected that the individual contribution of the consultant shall reflect the consultant's area of expertise; therefore, no consensus opinion (or report) will be accepted. Specific tasks and timings are itemized below:

1. Read and become familiar with the relevant documents provided in advance to the consultant;
2. Discuss potential agenda items with scientists in Woods Hole, MA, over December 3-5, 2001;
3. No later than January 7, 2002, submit a written report of guidelines, findings, analysis, and conclusions. The report should be addressed to the "UM Independent System for Peer Reviews," and sent to David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report should be prefaced with an executive summary of findings and/or recommendations.
2. The main body of the report should consist of a background, description of review activities, summary of findings, and conclusions/recommendations.
3. The report should also include as separate appendices the bibliography of materials provided by the Center for Independent Experts and the center and a copy of the statement of work.
4. Individuals shall be provided with an electronic version of a bibliography of background materials sent to all reviewers. Other material provided directly by the center must be added to the bibliography that can be returned as an appendix to the final report.

Appendix 1 BRIEF REVIEW OF SURVEY DESIGN ISSUES

This appendix (11 page 4,300 word document) has been prepared to support the review. It contains the following sections:

Introduction

Objectives

Stratification

Proportions of time allocated to transects and trawls

Pre-planned track design options; systematic or random designs

Pre-planned track design options; parallel or diagonal designs

Number of Transects

Transect direction

Adaptive surveys

Extending or reducing the area adaptively

Increasing track density in areas of high abundance

The contractual requirements for UM assign copyright for the report to UM. I am currently unable to assign copyright for this material so I am unable to submit it with the report. The section concerned has been prepared under the contract and will be sent direct to NEFSC.

John Simmonds 7/1/2001